SOME RECENT WORK ON DIFFUSION.[1]

THE subject of my lecture is one which, though essentially of a physical nature, had its origin in what may be regarded as a no man's land, a strip of neutral territory which can be claimed exclusively neither by the physicists nor the biologists.

An attempt to reconcile some apparently contradictory facts connected with the nutrition of plants has led, somewhat unexpectedly, to an extension of the laws of gaseous diffusion, so that we shall have to deal with one of those comparatively rare cases in which biology has been able to react to some extent on physics.

It has long been known that the primary source of the carbon of all plants is the carbonic acid existing in small quantities in ordinary atmospheric air, and that their green parts, more especially the leaves, are able to utilise the energy of sunlight in decomposing the carbonic acid and water and building up from their elements a whole series of substances, such as sugars and starch, which contribute directly to the nutrition of the plant.

The immediate seat of this synthetic and assimilatory process is found in the minute green chlorophyll granules which occur in great numbers within the cells of the leaf tissue, and one of the first problems to be dealt with in the study of the process is to show in what manner the highly dilute carbonic acid of the air can gain entry into the leaf with sufficient rapidity to supply these assimilating centres with material for the needs of the plant.

In a typical leaf, such as is represented in section in the diagram, both sides are covered with a cuticle and epidermis pierced at regular intervals on one or both sides with extremely minute openings, whose size is capable of being regulated according to the requirements of the plant. These are the *stomates* which open out into a relatively large cavity within the leaf, and this cavity in turn communicates with the numerous and roomy air-spaces between the cells containing the green chlorophyll granules.

One of the most important functions of the stomates is undoubtedly to regulate the transpiration of water from the plant, but the question of how far these minute openings play a part in the interchanges of gases between the interior of the leaf and the outer air has been a subject of very lively controversy.

It is now about thirty years since the eminent French chemist, Boussingault, came to the conclusion that the carbonic acid of the air gains access to the leaf, not through the *stomates*, but through the continuous substance of the cuticle and epidermis, by a process of *osmosis* similar to that by which carbonic acid had been shown by Graham to pass through a thin film of india-rubber.

So convincing did Boussingault's experiments and arguments appear to his contemporaries that this view became an article of faith for something like a quarter of a century, until, in fact, some five or six years ago, when Mr. F. Frost Blackman took up the subject and proceeded most inconsiderately to shatter all the most cherished statements of our text-books on this question.

I regret that time will not allow me to do more than state the general conclusions at which Mr. Blackman arrived and which may be briefly summarised as follows :

In the first place there is no appreciable passage of atmospheric carbonic acid through the surface of a leaf which is naturally devoid of stomates, such, for instance, as the upper surface of a normal leaf, which is quite imperforate ; neither is any entry of carbonic acid possible when the stomates have been artificially blocked or made to close spontaneously.

In additition to this, if a leaf has stomates on both surfaces the relative in-take of carbonic acid by those surfaces bears a distinct relation to the distribution of the stomates.

We can, in fact, no longer doubt that when a leaf is respiring or assimilating mere osmosis of carbonic acid through the substance of the cuticle and epidermis plays little or no part in the gaseous exchanges, and that whatever the exact nature of the process may be it must be carried on exclusively by the minute openings of the stomates.

Since anything like a mass movement of the air through these openings is out of the question, we must look to the phenomena of *diffusion* for the true explanation, and especially to that form of it which was first described by Graham as *free diffusion*, that is to say the natural tendency possessed by gases or liquids to form a perfect mixture when they are in contact with each other and there is no partition of any kind between them.

This spontaneous mixing is quite independent of any currents or mass movements of any kind, and is brought about by the gradual interpenetration of the molecules of the one gas or liquid by the molecules of the other.

As an example of this kind of diffusion I have here a cylinder which a few weeks ago was partly filled with 5 per cent. gelatine solution. After the gelatine had set, the cylinder was filled up with a highly-coloured solution of a copper salt, which you now see has permeated the jelly to a certain depth. There has been no mixing of the solutions in the ordinary sense of the word, for the gelatine is virtually a solid. The effect has been produced by the molecules of the coloured copper salt, by reason of their rapid movement in all directions, gradually penetrating into the spaces between the molecules of the gelatine layer. Given a sufficient length of time and there would be an equal partition of the coloured substance between the two layers.

Diffusion takes place, as is well known, much more rapidly with gases than with liquids. Had our cylinder contained, for instance, carbonic acid in the lower half and air in the upper, a complete mixing would have taken place in a comparatively short time, even if all convection currents had been prevented.

The classical researches of Graham on the diffusion of gases through thin porous septa established the general law that the rate of diffusion of the different gases, under identical conditions, varies inversely as the square roots of their respective densities. Graham's results, however, only acquaint us with the *relative* velocities of diffusion, whereas for the particular problem which we have before us we must know the *absolute* velocities of diffusion under strictly defined conditions.

It is mainly to the Viennese school of physicists, and especially to Prof. Loschmidt, that we owe our present knowledge of the actual rate of penetration of one gas by another in free diffusion.

By observing the speed with which different pairs of gases spontaneously mix in a tube, Loschmidt was able to deduce certain *absolute values* expressing the velocity of their interpenetration.

Some of these results for different pairs of gases are given in the diagram, the last column representing the "constant of diffusivity" expressed in centimetre-gram-second units.

Let us consider the constant for carbonic acid and air, which at 0° C. is ·142. This means that when air and carbonic acid gas are freely diffusing into each other, an amount of either gas corresponding to ·142 cubic centimetre will pass in one second of time across an area of one square centimetre when the partial pressure of the gas varies by one atmosphere in one centimetre of length.

Now when we come to apply these absolute values of diffusivity to the passage of the extremely dilute CO_2 of the air into the leaf stomates (whose dimensions can of course be determined), we find that free diffusion through these openings is apparently able to account for only a portion of the gas which we know must enter the leaf, unless we make some extremely improbable assumptions as to the very low point at which the partial pressure of the carbonic acid is maintained immediately under the apertures.

I shall not, however, trouble you with the calculations on which this statement is based, since I prefer to put the matter in a more concrete form, which has also the advantage of emphasising the extraordinary power which an assimilating leaf possesses of extracting carbonic acid from its surrounding air.

There are two methods by which we can determine the actual amount of atmospheric carbonic acid used up by an assimilating leaf, one a direct the other an indirect method.

Part of the apparatus used in the direct method is shown on the table.

The leaf, which may be still attached to the plant, is enclosed in a glazed case, through which a measured current of air is drawn of which the carbonic acid content is accurately known. When the air emerges from the case it passes through an absorption apparatus, which retains the whole of the CO_2 left in the air after passing over the leaf. This absorbed carbonic acid is determined at the close of the experiment, and we then have all the data for estimating the carbonic acid abstracted from the air by the leaf. The area of the leaf being known, the CO_2 absorbed can be referred to a unit area of leaf and a unit time.

By the indirect method, which is due to Sachs, the actual increase in dry weight of a given area of an assimilating leaf is determined, and since this increase in weight is due to

substances having a definite percentage of carbon a simple calculation enables us to determine the equivalent amount of carbonic acid abstracted from the air.

By such methods as this it can be shown that an actively assimilating leaf, such as that of the Catalpa tree, in full daylight, and under favourable conditions of temperature, can take in carbonic acid from the air at the rate of about 1/10th cubic centimetre per hour for each square centimetre of leaf.

Since there are only about three volumes of carbonic acid in 10,000 volumes of ordinary air, this must mean that in a single hour the under surface of the leaf will take in as much carbonic acid as is contained in a column of air about eight feet long, and having the same area of cross-section as the leaf.

But this remarkable power of an assimilating leaf will be better appreciated if we compare it with a liquid surface of a strong solution of caustic alkali, which is known to have such a great avidity for carbonic acid.

We can investigate the absorptive power of such solutions for the carbonic acid of the air under fixed and controllable conditions by using a form of apparatus which I have on the table, and which can be examined at the close of the lecture. It is so arranged that an air current of known velocity can be drawn over the surface of the absorbing solution which has a known area.

When a very low velocity of the air current has been reached the amount of absorption becomes constant at ordinary temperatures at about ·17 c.c. of carbonic acid per square c.m. of surface per hour.

So we see that a leaf, assimilating under natural conditions, is taking in carbonic acid from the air more than half as fast as a surface of the same area would do if it were wetted with a constantly renewed film of a strong solution of caustic alkali submitted to a strong current of air.

This is in itself a somewhat remarkable conclusion, but what are we to say to a proposition which would limit the absorptive power of the leaf surface to the extremely small apertures of the stomates?

In a leaf such as we have been considering, the aggregate area of the openings of the stomates, when expanded to their widest, amounts to less than *one per cent.* of the total leaf surface, so that if the entry of the CO_2 takes place exclusively by these openings we must conclude that it goes in more than fifty times faster than it would do if the mouth of each one of these minute openings were filled with a constantly renewed solution of strong caustic alkali.

Such facts make it difficult unreservedly to accept the view that the gaseous exchanges in leaves are really carried on exclusively by the stomates, which occupy such a small fraction of the leaf surface. On the other hand, the direct experimental evidence in favour of this view is overwhelming, so that we apparently find ourselves on the horns of a dilemma.

There appeared to be only one way out of the difficulty, that was to assume that the leaf knows more about the laws of free diffusion than we do, and has adapted itself to some physical principles which have hitherto escaped notice. This was found to be the case when the structure of the leaf was regarded as a piece of physical apparatus for promoting rapid diffusion.

I do not propose to take you through the various and tedious stages by which the true explanation was reached, but will attempt, as far as possible, to short-circuit the current of the argument.

In the first place I wish to call your attention to a particular mode of free diffusion which, in gases, has been but little studied, but which has a very direct bearing on diffusion in the living leaf, where one of the constituents of the diffusing gases, the carbonic acid, is very small in amount compared with the others.

Let us for a moment concentrate our attention on the air which is contained in this open glass cylinder, and endeavour to picture to our minds the jostling crowds of the perfectly elastic molecules of the various gases, flying hither and thither in all imaginable directions and coming into frequent collision with each other and the sides of the containing vessel.

Now in this jostling throng there is a certain proportion of molecules of *carbonic acid,* which we will imagine for the moment are distinguished from the molecules of the other gases by some difference in colour—let us suppose them to be *green.*

Now further consider a plane surface in the contained air of the cylinder; from the dynamical theory of gases it follows that in any given interval of time, temperature and pressure remaining constant, the same average number of the "green" molecules will cross this imaginary plane in opposite directions, and since this will be true for any plane surface, no matter where we take it within the cylinder, there can be no change in the average distribution of the "green" molecules throughout the cylinder—in other words, no change in any part of the cylinder in the composition of the air as regards its carbonic acid content.

But now let us imagine that the bottom of the cylinder is suddenly made capable of absorbing carbonic acid, say by the introduction, without any disturbance of the air, of a little solution of caustic soda or caustic potash. The "green" molecules which now strike the bottom of the cylinder at all imaginable angles of incidence will not all rebound as they originally did, but will be to a large extent trapped in their to and fro excursions, so that in the very first brief interval of time a very thin stratum of air, parallel to and immediately above the absorbing surface, will be partially freed from its "green" molecules.

Now consider the kind of exchange of "green" molecules which occurs in the next very brief interval of time between this partially depleted layer at the bottom and the one immediately above it. The rate of exchange across the imaginary plane dividing these two contiguous layers can no longer be equal and opposite since the number of "green" molecules in the upper stratum is greater than that in the lower. A larger number of the "green" molecules must consequently pass in a given brief interval of time from the higher to the lower stratum than from the lower to the higher; in other words, the *balance of exchange* is in favour of the lower layer. This state of affairs will rapidly propagate itself upwards until the mouth of the cylinder is reached, and, provided the air outside the cylinder is kept of the same composition and the absorptive power of the bottom of the cylinder is also kept constant, these *uncompensated balances of exchange* between the imaginary layers may be regarded as constituting a steady *flow* or *drift* of the "green" molecules down the tube towards the absorbent surface.

Although within the column there is this constant flow of carbonic acid molecules in the general direction of the axis of the tube, the system as a whole may now be regarded as static as long as all the conditions remain unchanged. The flow is, then, strictly analogous to the "flow" of heat in a bar of metal which is kept with its two ends at a uniform difference of temperature, or to the flow of electricity in a conductor between two regions maintained at a constant difference of potential; and static diffusion admits of precisely the same simple mathematical treatment as these phenomena of conduction of heat or electricity when we come to its quantitative study.

In such an imaginary experiment as we have been considering it is clear that the amount of carbonic acid in the air of the cylinder must vary uniformly from a maximum at the top of the cylinder to a vanishing point at the bottom, so that if the CO_2 really had the green colour which, for purposes of argument, we have attributed to it, the depth of colour of the air column would uniformly diminish from top to bottom.

This can be illustrated by the diffusion of a coloured copper salt down a gelatine column. If this column were cut off just where the colour ceases to be perceptible, and the cut end were immersed in water to carry off the diffusing salt as fast as it came through the column, then if the upper end of the column remained in contact with the coloured copper solution we should ultimately get a constant steady flow of the salt down the column.

Under these conditions it can be readily shown, both experimentally and theoretically, that the actual amount of substance diffusing down the column in a given time will, in the first place, be directly proportional to the difference in the concentration of the diffusing substance at the two ends of the column; it will also be directly proportional to the *area* of cross-section of the column, but inversely proportional to its length.

The fact which for the moment I wish you to bear in mind is that, all other things being the same, the amount of diffusion down a column of this kind *varies directly as the area of the cross-section of the column.*

This is roughly illustrated by these two cylindrical columns of gelatine of different diameters, down which a coloured solution has been diffusing for equal times.

The salt has penetrated both columns to the same depth, and the gradation of colour is also the same, a proof that the rates of diffusion down the columns must be proportional to their areas of cross-section.

But now let us consider what will happen if instead of varying the width of the column throughout its entire length we only partially obstruct the cylinder somewhere in the line of flow, say by means of a thin diaphragm pierced with a single circular hole of less diameter than the bore of the tube.

We must resort to experiment to answer this question.

Suppose we take a series of exactly similar flasks, such as I have here, and produce a steady flow of atmospheric carbonic acid down their necks by partially filling each flask with a solution of caustic soda, the amount of carbonic acid entering the flasks being determined by subsequent titration of the soda solution. We can then study the effect produced by partially obstructing the mouths of the flasks with thin discs of metal or celluloid pierced with a single hole of definite size.

The results of a series of experiments of this kind are given in Table I., and you will see that under these conditions the amounts of carbonic acid diffusing down the cylindrical necks in a given time are not proportional to the areas of the apertures, as might reasonably have been expected, but are directly proportional to their *diameters*.

TABLE I.

Diffusion of Atmospheric CO_2 through single apertures of varying size.

Diameter of Aperture	CO_2 diffused per hour	CO_2 diffused per sq. cm. per hour	Ratio of Areas	Ratio of Diameters	R^a to of CO_2 diffused
mm.	c.c.	c.c.			
22·7	·2380	·0588	1·00	1·00	1·00
6·03	·0625	·2186	·07	·26	·26
3·23	·0398	·4855	·023	·14	·16
2·11	·0260	·8253	·008	·093	·10

This, of course, implies that as we make the aperture smaller the flow through a given unit of its area is proportionately increased; in other words, the acceleration of flow is *inversely proportional to the diameters of the apertures.*

This unexpected fact, which lies at the root of the whole question we are considering to-night, may be experimentally illustrated in a variety of ways.

We may, for instance, cause the aqueous vapour of the air to diffuse into a similar series of flasks, using in this case strong sulphuric acid as the absorbent, and determining the amount of diffusion of the water vapour by weighing the flasks from time to time. You will see from the results of such an experiment that the diffusion rates again follow pretty closely the ratios of the diameters of the apertures, and are widely divergent from the ratios of areas. (See Table II.)

TABLE II.

Diffusion of Aqueous Vapour through apertures of varying size.

Diameter of Apertures	Ratio of Areas	Ratio of Diameters	Ratio of Diffusion for equal times
mm.			
2·117	1·0	1·0	1·0
3·233	2·3	1·52	1·55
5·840	7·6	2·75	2·54

This "diameter law" is also applicable to circular liquid surfaces, the amount of absorption or evaporation from such surfaces varying, under certain conditions, not in accordance with the area of the surfaces, as might have been expected, but with their diameters.

I have here a short burette-like tube with a wide rim of metal round the top. When this tube is completely filled by letting in a solution of caustic soda we have a circular surface of the solution lying in the same plane as the rim. When this has

been exposed to the air for a given time the carbonic acid absorbed by the disc of liquid can be determined by drawing off and titrating.

If such absorptive discs of different dimensions are exposed to air which is in *slight movement*, we shall find that the carbonic acid absorbed is proportional to the *area* of the surface. The smaller, however, we make the discs, and the greater precautions we take to keep the air over them perfectly still, the nearer do the absorptions become proportional to the diameters. (See Table III.)

There is always, however, more difficulty in obtaining these results with plane absorbing surfaces than by diffusion through a perforated diaphragm. The reason for this will be apparent later.

TABLE III.

Absorption of Atmospheric CO_2 by Circular Surfaces of Solutions of Caustic Alkali.

Diameter of Surface mm.	Ratio of Areas.	Ratio of Diameters.	Mean Ratio of Areas and Diameters.	Ratio of CO_2 absorbed.
10·25	1·0	1·0	1·0	1·0
20·25	3·9	1·9	2·9	3·0
29·25	8·1	2·8	5·4	5·3
40·00	15·2	3·9	9·5	9·2
5·0	1·0	1·0	—	1·0
10·25	4·2	2·05	—	2·47

Before entering on an explanation of these facts I wish you to note a very important conclusion to be drawn from them, and one which readily admits of experimental verification.

We have seen that when we partially obstruct the diffusive flow of a gas or liquid by a thin septum with a single circular perforation, the velocity of the flow through each unit area of aperture increases as the diameter of the aperture decreases.

One might, therefore, expect that if a number of fine holes were suitably arranged in such a septum, the acceleration of flow through the individual holes might assume such proportions that a perforated septum of this kind would exercise little or no obstruction on the diffusive flow, although in such a case the aggregate area of the holes might only represent a small fraction of the total area of the obstructing septum.

Strange and paradoxical as such a conclusion may at first sight appear, it will bear the test of experiment.

I have here a thin film of celluloid; in fact, a piece of the ordinary Kodak roller-film. This has been perforated with holes about ·4 millimetre in diameter, arranged at a little more than 2·5 diameters apart, so that there are just one hundred of such perforations on a square centimetre of area. The clear holes represent about 1/10th of the area of the film, 9/10th of the sieve being blocked up with impervious celluloid.

Here are two columns of gelatine, down which a blue solution of copper-ammonium sulphate has been diffusing for equal times. One of these columns is unobstructed in any way, being in direct contact with the coloured liquid. In the other case a finely perforated celluloid film has been interposed, which has the effect of blocking out 9/10ths of the cross-section of the column. You see that, notwithstanding this, there is no appreciable difference in the amounts of coloured salt which have diffused in the two cases; the salt has, in fact, gone through the finely-pierced septum as readily as if no obstruction were present.[1]

We find that exactly the same holds good with gaseous diffusion.

If finely perforated septa of this kind are luted on to short tubes containing caustic soda and are exposed to still air, the amount of carbonic acid diffusing through the holes in the diaphragm can be compared with the amount which we know would diffuse down the open tube under like conditions. Some results of this kind are given in Table IV.

[1] The celluloid film is itself not permeable.

TABLE IV.

Diffusion of Atmospheric CO_2 through Multiperforate Septa into Tube 4 c.m. long. Diameter of Holes ·38o m.m.

No. of Holes per sq. cm.	Diameters Apart	CO_2 Diffusing through Septum per hour c.c.	Open Tube Diffusion per hour c.c.	Percentage of Septum Diffusion on Open Tube Diffusion.	Percentage area of Cross-section occupied by Holes.
100	2·63	·361	·346	104·3	11·34
25	5·26	·148	·342	43·2	2·82
11·11	7·8	·131	·352	37·2	1·25
6·25	10·52	·110	·353	31·1	·70
15·7	15·7	·068	·334	20·4	·31

I must now ask you to follow me in a somewhat theoretical excursion in quest of an explanation of these curious facts.

(*To be continued.*)

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—The following have been elected public examiners:—Mr. R. T. Glazebrook, in physics; Mr. P. Elford, in chemistry; Prof. F. Gotch, in physiology.

The curators of the University Chest have been authorised to spend a sum not exceeding 1400*l*. in certain extensions of the Chemical Department which are necessitated by the loss of the laboratory known as the "Glastonbury Kitchen." The latter is now required as access to the new Radcliffe Library.

A proposal to permit candidates for the degree of Bachelor of Letters or Science to keep more than one term of University residence in the year by residence during the vacation has been rejected.

A proposal to provide access for wheeled traffic to the Departments of Physiology, Human Anatomy and Pathology at the back of the University Museum has also been rejected owing to the opposition of those who regard this as an encroachment upon the University Park.

The Junior Scientific Club held their 226th meeting on May 31. A paper was read by E. Walls, entitled "The Quest of the Philosopher's Stone." Prof. Silvanus Thompson delivered the Boyle Lecture on June 6, on "Magnetism in Growth."

CAMBRIDGE.—In the mathematical tripos, part i., the senior wrangler is Mr. A. Brown, of Caius College, a Ferguson student from Edinburgh. Miss Reynolds, of Newnham, is bracketed 11th wrangler. Three names appear in the first class of part ii.: Mr. J. E. Wright, Trinity (senior wrangler 1890); Mr. T. H. Havelock, St. John's (15th wrangler); and Mr. J. Chadwick, Pembroke (5th wrangler). Miss W. M. Hudson, Newnham, is in the first division of the first class (bracketed 8th wrangler 1890).

The professor of pathology announces ten separate courses of lectures and practical work to be given in the long vacation, beginning July 8.

PROF. R. W. WOOD, of the University of Wisconsin, has been appointed professor of physics in the Johns Hopkins University, in succession to the late Prof. H. A. Rowland.

WE learn from *Science* that the Wisconsin Legislature has granted 210,000 dollars to the University of Wisconsin, at Madison, in addition to the regular income previously derived from the State. Of this sum 150,000 dollars is for a new building for the College of Agriculture, which is to house the administration offices of this department and the experiment station as well as the departments of bacteriology and chemistry. This College also receives 10,000 dollars annual increase to its present income. The College of Engineering receives 30,000 dollars for equipment of its new building, which was provided by the last Legislature; also 7500 dollars annual increase in income. The newly organised School of Commerce secures 3500 dollars annual increase.

DR. H. M. KYLE has been appointed naturalist to the Marine Biological Association and fisheries' instructor for the county of Devon. Dr. Kyle is a distinguished graduate of the University of St. Andrews, having gained the rector's prize for an essay on evolution and having held successively the Fisheries' prize, the Berry scholarship (100*l*.) and, for three years, the Exhibition of 1851 scholarship (150*l*.) for original researches in connection with the fisheries. His studies for seven years have been devoted to marine zoology and the scientific treatment of the problems of the fisheries at the chief marine laboratories of Europe, including Naples, Plymouth, &c., and both the old laboratory and the new (Gatty) laboratory at St. Andrews, where he was trained.

WE learn from the *Berliner Klinische Wochenschrift* that the second annual congress of the German Association for School Hygiene, which was founded about two years ago for the purpose of studying and promoting all matters relating to health and hygiene in connection with schools, was held at Wiesbaden on May 31. The municipal authorities of that city placed the "Curhaus" at the disposal of the council of that association, where all the official meetings were held during the congress. The attendance was a large and a representative one, and the programme contained many important and highly instructive subjects, of which the following may particularly be mentioned: (1) the new Prussian school reform in relation to school-hygiene; (2) the hygienic condition of German schools in general, with special reference to that of Wiesbaden; (3) the prevention of infectious diseases regarded from a general point of view, with special reference to the spread of tuberculous affections amongst school children.

THE *Educational News* of Scotland states that the following is the list of candidates for the chair of natural philosophy in Edinburgh University, vacant through the resignation of Prof. Tait:—Prof. J. C. Beattie, South African College, Cape Town; Prof. G. H. Bryan, F.R.S., University College, North Wales; Dr. Charles Chree, F.R.S., National Physical Laboratory, Richmond; Dr. Cargill G. Knott, University of Edinburgh; Prof. J. P. Kuenen, University College, Dundee; Dr. Charles H. Lees, Owens College, Manchester; Mr. David B. Mair, Civil Service Commission, London; Prof. J. A. M'Clelland, University College, Dublin; Prof. J. G. MacGregor, F.R.S., Dalhousie University, Halifax, U.S.A.; Prof. Karl Pearson, F.R.S., University College, London; Mr. G. F. C. Searle, Cambridge; Mr. George W. Walker, Cambridge; Mr. Gilbert T. Walker, Cambridge; Mr. C. T. R. Wilson, F.R.S., Cambridge.

PROF. RAMSAY expressed the views of a number of teachers and investigators in the annual oration delivered by him at University College, London, last week, on "The Functions of a University." The essential principle of University work should be research. This, said Prof. Ramsay, should be the goal to be clearly kept in view in the philosophical faculties of Universities. He was not one of those who would urge that a young man should not learn a great deal of what had been already discovered before he attempted to soar on his own wings. But there was all the difference in the world between the point of view of the student who read in order to qualify for an examination, or to gain a prize or scholarship, and the student who read because he knew that thus he would acquire knowledge which might be used as a basis of new knowledge. It was that spirit in which our Universities were so lamentably deficient; it was that spirit which had contributed to the success of the Teutonic nations, and which was beginning to influence the United States. A University which did not increase knowledge might be a technical school or a coaching establishment, but it had no claim to the name University. The best way of fitting young men for the manifold requirements of the Empire was to give them the power of advancing knowledge.

SOCIETIES AND ACADEMIES.

LONDON.

Chemical Society, May 16.—Prof. Emerson Reynolds, president, in the chair.—The following papers were read:—Derivatives of methylfurfural, by H. J. H. Fenton and Miss M. Gostling. A simple method of obtaining pure methylfurfural is described.—Optically active nitrogen compounds and their bearing on the valency of nitrogen; dextro- and lævo-α-benzyl-